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February 12, 1965

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Subj: AP/3 Stereoplotter

Gentlemen:

We wish to present to you an unsolicited proposal for furnishing you a stereoplotting system which we hope will be of interest to you. This system is known as the [redacted] Analytical Stereoplotter, AP/3.

The Model AP/3 system is basically a further development of the concepts embodied in the now standard AP/2 instrument which is being procured by the U. S. Air Force and the U. S. Army.

We feel that with a certain degree of developmental work additional capabilities can be added to the heretofore AP/2 system which will greatly enhance the capabilities of this system.

More specifically, the performance characteristics of the proposed development will not only meet the existing performance specifications for the AP/2 system (military terminology: AS-11A system) but, in addition, will have the following capabilities.

The optical magnifications available will range up to 100 X with a suitable resolution to exploit such magnifications.

The accuracy of the system shall be designed to attain a RMSE of 4 microns or less over the entire area of a 9" x 9" aerial photograph and over areas of 2" x 2", an RMSE of 2 microns or better.

The system shall be capable of stereoplotting with aerial frame photography, aerial panoramic photography and terrestrial frame photography. Programs for focal lengths from 1" to 48" with photography formats up to 9" x 9" will be provided.

Provision will be provided to punch or type out model coordinates or photo coordinates as desired. These coordinates may be actual current values or the average of several readings up to a total of at least five readings of any point. Panel controls will be provided to select the desired output.

The programs provided will calculate three dimensional vector distance, D_m, between any two points in the stereo model. Each point may be the average of several readings of the coordinates of that point if desired. It shall be possible to print out in punch or type the quantity D_m.

A Model 35 Teletype printer with keyboard will be provided. The ASA standard tape code will be employed.

The AP/3 will be provided with a 50-character per second, mechanical tape reader.

The coordinatograph, or X-Y plotter, will be driven by servo motors.

The Veltropolo device will be digital in nature, similar to that used on the Model AP/C Analytical Stereoplotter. This will provide greater accuracy and control of the Veltropolo device.

The general appearance, both as to size and format, of the AP/3 system will be similar to the AP/2 system with the exception that an additional computer cabinet will be required to house additional computer circuitry. However, should image-correlation circuitry be added at a later date, which may be possible as a retrofit, no additional cabinet will be required to house the correlation circuitry.

The above stated performance characteristics are in addition to those stated in the attached specification for the AP/2 system. It is understood that the AP/3 system will meet all requirements of the AP/2 system in addition to the additional performance to be developed for the AP/3 system. Naturally where such developments represent improvements on the AP/2 design, the lesser desired AP/2 characteristics will not also be provided.

The cost of the first developed AP/3 system is [redacted] delivered and installed at any site in the Washington, D.C. area, not including U. S. Customs or taxes, if any. Delivery of the system can be made ten months after receipt and acceptance of order. Additional program documentation and manuals describing the theory of operation and maintenance of the equipment will be delivered twelve months after receipt of order. This quotation will remain valid until 1 April 1965.

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We would be pleased to consider any suggestions or revisions of the technical characteristics which you might have in mind. Naturally, such revisions would affect the quoted price either upwards or downwards. Please note that no quotation was made for automation of the system which would be perfectly feasible at additional cost. It will also be possible to add on such automation at a later date, as a retrofit, with minimum difficulty.

We hope to have the pleasure of hearing from you in the near future.

Sincerely yours,

[redacted] STAT

Executive Vice President

SJF:en

Encl.

TECHNICAL SPECIFICATIONS
ANALYTICAL STEREOPLOTTER SYSTEM, AP/2

1. Service Conditions - The Plotter Group shall be constructed to operate under any combination of the service conditions specified in the general specification with exceptions and additions as follows:

1.1 Climatic

a. Ambient Temperatures

(1) Operating	21°C(69.8°F) to 24°C (75.2°F)
(2) Non Operating	4.4°C (39.9°F) to 54°C (129.2°F)
(3) Packaged for Shipment	-29°C (-20°F) to 54°C (129.2°F)

1.2 Relative Humidity

a. Operating	45 - 55 percent
b. Non Operating	0 - 95 percent
c. Packaged for shipment	0 - 100 percent

2. Mechanical - The Plotter Group shall not suffer damage nor fail to give required performance when subjected to shock and vibration encountered in transit and handling.

3. Electrical - The Plotter Group shall operate from an alternative current (a-c) source of power with characteristics as specified below:

a. Potential and phase:

(1) 208 plus 26 to minus 8 volts line to line; four wire, three phase, or 120 plus 6 to minus 6 volts, single phase.

b. Fluctuation in potential: plus or minus 2.5 volts (within the limits of a above).

c. Maximum rate of change of voltage: plus or minus 2 percent per second.

d. Frequency: 60 plus or minus 1 cycle per second (cps).

e. Harmonic content: 3.5 percent.

4. Lightweight Material - Wherever practical lightweight, highstrength materials shall be used.

5. Component Construction

5.1 Plug-in Units - To facilitate maintenance miniaturized replaceable package units shall be used in the electronic portions of the projector.

5.2 Active Components - All electronic and control portions of the Plotter Group shall be transistorized where this type of circuitry is practical and feasible.

5.3 Improper Operation Protection

5.3.1 Sensing of Incompatible Situation - As certain combinations of the photogrammetric variables do not represent physically realizable situations, the Plotter Group shall be capable of sensing and indicating to the operator any incompatible condition which might arise in order to prevent damage to the instrument.

5.3.2 Emergency Stops - Emergency stops shall be provided on the Plotter Group to minimize damage in the event of malfunction of the equipment.

5.3.3 Alarms - Visual or aural fuse alarms shall be provided on all critical units of each component to indicate failures of malfunction within these units.

6. Performance Requirements -

6.1 Purpose - The purpose of the Plotter Group is to provide contour charts with such planimetary as is available from a pair of diapositives. The Plotter Group shall contain a digital computer to provide planimetric and height information on the basis of X and Y parallax data, photo coordinate measurements, interior orientation data, and sufficient ground control. The overall accuracy of the equipment shall be 5 microns root mean square error at model scale.

6.2 Description of Inputs -

6.2.1 Orientation Input - The Plotter Group shall be able to accept the following type of input information:

a. X,Y,Z Cartesian coordinates of control in a given coordinate system with arbitrary origin.

b. Base control plot of photo-identifiable control.

c. Values of exterior orientation for the photos.

6.2.2 Lens Distortion Adjustment - The lens distortion adjustment shall be of such value that the entry of which will not cause more than 2½ microns (at model scale) error in the final stereoplotter output. It is desirable that lens distortion be represented by a radial and tangential value.

6.2.3 Film Shrinkage - Correction for film shrinkage distortion shall be entered for each of X and Y values respectively and independently.

6.2.4 Earth Curvature - The computer shall take into account the effects of earth curvature when computing the differential X and Y motion commands inserted into the individual optical trains. The computer shall utilize the approximation:

$$h = \frac{S^2}{2R}$$

where h is the departure of the earth (assumed spherical) from the datum plane, S is the distance from the point of tangency of the datum plane and R is the radius of the earth. The datum plane for this computation shall be that defined in paragraph 6.12.3, h shall be computed to three significant figures.

6.2.5 Atmospheric Refraction - The computer shall correct for the effects which are caused by total atmospheric refraction. The atmospheric model for this computation shall be that contained in the "The ARDC Model Atmosphere, 1959", Air Force Surveys in Geophysics 115, Geophysics Research Directorate, AFCRD, ARDC, August 1959.

6.2.6 Systematic Effects, Corrections, and Plotter Calibration Constants - The Plotter Group shall accept input constants which shall account for the "taking" camera principal distance (calibrated focal length), the position of the principal point, lens distortion, and film shrinkage. Additional detailed requirements are given in paragraphs 6.2.2 and 6.2.3 covering the last two effects. In addition the Plotter Group shall contain provisions to account for additional special systematic error such as plotter calibration. Capability shall be provided for entering, on punched paper tape, data which shall effect a simultaneous displacement of both viewing heads by the same amount and in the same direction. It shall be possible to obtain simultaneously:

a. Displacement in X as a function of X

b. Displacement in X as a function of Y

c. Displacement in Y as a function of X

d. Displacement in Y as a function of Y

6.2.7 Type of Physical Input - The Plotter Group shall have the following type inputs:

a. Contact positive transparencies, made emulsion to emulsion, up to 9½ inches by 9½ inches maximum.

b. Contact positive transparencies, made contact emulsion to emulsion on glass plate up to 9½ inches by 9½ inches maximum.

6.2.8 Convergent Panoramic Photography - Provision shall be made in the Plotter Group to handle the additional mathematics and controlled machine motions required by panoramic and frame photography with a nominal convergence angle up to 65°.

6.2.8.1 Model Distortion - The computer shall be capable of generating corrections to the model coordinates (X, Y, Z) based upon power series equations of the form:

$$P_x = a_1 X_m^* + a_2 Y_m^* + a_3 X_m^{*2} + a_4 X_m^* Y_m^* + a_5 Y_m^{*2} + a_6 X_m^{*3}$$
$$+ a_7 X_m^{*2} Y_m^* + a_8 X_m^* Y_m^{*2} + a_9 Y_m^{*3}$$

$$P_y = b_1 X_m^* + b_2 Y_m^* + b_3 X_m^{*2} + b_4 X_m^* Y_m^* + b_5 Y_m^{*2} + b_6 X_m^{*3}$$
$$+ b_7 X_m^{*2} Y_m^* + b_8 X_m^* Y_m^{*2} + b_9 Y_m^{*3}$$

$$P_z = c_1 X_m^* + c_2 Y_m^* + c_3 X_m^{*2} + c_4 X_m^* Y_m^* + c_5 Y_m^{*2} + c_6 X_m^{*3}$$
$$+ c_7 X_m^{*2} Y_m^* + c_8 X_m^* Y_m^{*2} + c_9 Y_m^{*3}$$

The coefficients of this equation will be determined external to the computer.

6.2.8.2 **Relative Vehicle Motion** - The computer shall establish corrections for motion of the camera relative to the earth during exposure. The correction equations shall be of the form:

$$\Delta \quad X_R = K_{XR}\, \Theta$$

$$\Delta \quad Y_R = K_{yr}\, \Theta$$

where K is a constant expressing the conditions of relative motion.

6.2.8.3 **Camera Orientation** - To accommodate changes in camera orientation during the exposure cycle of panoramic photography, the computer shall accept for each photograph, values of incremental changes in pitch, roll, and yaw as functions of the sweep angle. The rates of change shall be treated in the following manner:

$$\text{Pitch} \quad \phi = \phi_o + \left(\frac{d\phi}{d\Theta}\right) \Theta$$

$$\text{Roll} \quad w = w_o + \left(\frac{dw}{d\Theta}\right) \Theta$$

$$\text{Yaw} \quad k = k_o + \left(\frac{dk}{d\Theta}\right) \Theta$$

where ϕ_o, w_o, k_o are the given initial values of pitch, roll, and yaw, and the rates of change, $\frac{d\phi}{d\Theta}$, $\frac{dw}{d\Theta}$, $\frac{dk}{d\Theta}$ are assumed to be constants for any given photograph. Their magnitudes are equivalent to time-rates of change less than three minutes of arc per second of time.

6.2.8.4 **Model Coordinate Translation** - In the translation from the point of tangency in the model to the perspective center, the computer shall take into account displacement of the photo principal point resulting from incomplete image motion compensation caused by scale differences within the photography. The image motion compensation shall be in the form

$$\Delta \quad X_{IMC} = K_{IMC} \quad \sin \Theta$$

where K_{IMC} is a constant depending upon vehicle velocity, camera altitude and sweep time.

6.3 **Photogrammetric Variables** -

6.3.1 **Focal Length** - The focal length of the taking lens shall be 1 inch to 48 inches. The combination of focal length and format shall be limited to those of 120 degrees maximum included angle for vertical photography. The combination of focal length and format shall be limited to those of 90 degrees maximum including angle for convergent photography.

6.3.1.1 Overlap - The overlap along the line of flight shall be 50 percent to 100 percent.

6.3.2 Base/Height Ratio - The base height ratio shall be from 0 to 1.30 compatible with other inputs.

6.3.3 Exterior Orientation - The absolute value of exterior orientation angles of a single photograph shall have the following limits:

a. κ (yaw) 0 to 9° plus or minus

b. ϕ (pitch) 0 to 45° plus or minus

c. ω (roll) 0 to 9° plus or minus

6.3.4 Air Base Coordinates - The rectangular components of the air base at photo scale shall be:

a. b_x = 0 to 1250 mm

b. b_y = 0 to 1250 mm

c. b_z = 0 to 122 mm

6.4 Viewing Systems

6.4.1 Types of Viewing - The viewing system shall be a binocular train, providing direct orthoscopic viewing. Two separate optical systems are acceptable, one for conventional vertical frame photography, and one for convergent panoramic photography. This is to be accommodated by substituting the observation binocular units.

6.4.2 Magnification - Magnification shall consist of three discrete options of 6X, 10X, and 14X. The minimum field of view shall be 14 mm diameter at 14X, 20 mm diameter at 10X, and 24 mm at 6X. Design objective shall be established to provide an apparent field of view of 60 degrees.

6.4.2.1 Magnification Convergent Panoramic Photography - The equipment shall provide for continuous control of magnification of the convergent panoramic photography imagery by the associated computer. The magnification ratio, M/M_o is the ratio of the photo scale at any point on the photo with respect to the scale at the principal point. It shall be that which is between 0.7 and 1.4, computer to an accuracy of five percent from a basic setting of 20 x by using equations of the form:

$$M = \frac{1}{\cos \omega} \left[1 - \frac{X}{f} (3 \omega - 2 \sin \phi)\right]$$

The minimum field of view shall be 14 mm diameter at 14X, 10 mm diameter at 20X, and 7 mm diameter at 28X. This requirement shall be established to provide an apparent field of view of 60 degrees.

6.4.2.2 Dove Prism Rotation - Convergent Panoramic Photography - Provision shall be made to rotate the dove prisms in the optical trains by means of stepping motors, to achieve stereo vision of convergent panoramic photography. The rotation angle, oc, will have a range of $+20^{0}$ to -20^{0}, computed to an accuracy of one degree, using an equation of the form:

$$\alpha = 1.05 \sin \phi$$

6.4.3 Illumination - A tungsten source shall be provided to illuminate the photographs on the carriages. The brightness shall be satisfactory for use with the 14X magnification provided in the eyepieces and dense film areas, at the maximum setting of the illumination source. The brightness shall be adjustable via a control knob furnished to the operator. Each photograph carriage illumination source shall be independently controllable.

6.4.4 Freedom From Scratches or Abrasions - The components of the viewer shall not produce scratches, abrasions or other marks which will damage the film transparencies or diapositives.

6.4.5 Orthoscopic Viewer Performance - The instrument shall visually resolve no less than 100 lines per millimeter high contrast and 70 lines per millimeter low contrast (0.3 log contrast), and shall provide for maximum functional utility.

6.4.5.1 Orthoscopic Viewer Performance - Convergent Panoramic Photography - The objective shall be that the panoramic optical chain shall visually resolve no less than 80 lines per millimeter high contrast and 55 lines per millimeter low contrast (0.3 log contrast) and shall provide for maximum comfort to the operator during sustained operation while providing maximum functional utility.

6.4.6 Optics - The two (2) optics shall have focal lengths matched to within 1 percent. The optics shall be suitable for viewing film positive transparencies and glass plate diapositives. When viewing, the optics shall be free from apparent distortions and aberrations. All mirrors shall be front surfaced and overcoated. An exit pupil of at least 7 mm at 8X magnification shall be provided in each eyepiece. At higher magnifications the exit pupil shall be proportionately smaller reached 3.5 mm at 14X magnification. The eyepieces shall afford no less than 20 mm eye relief.

6.4.6.1 Optics - Convergent Panoramic Photography - The optics shall be suitable for viewing film positive transparencies and glass plate diapositives. When viewing, the optics shall be free from apparent distortions and aberrations. All mirrors shall be front surfaced and overcoated. An exit pupil of at least 2.5 mm at 20X magnification shall be provided in each eyepiece. At higher magnifications the exit pupil shall be proportionally smaller, reaching 14 mm, magnifications at 28X. The eyepieces shall afford no less than 20 mm eye relief.

6.4.7 Focus - Individual focus shall be provided for each eyepiece from -4 to +4 diopters.

6.4.7.1 Focus - Convergent Panoramic Photography - Focus of the optical system shall not be affected by the variation of magnification.

6.4.8 Inter-Ocular Distance - The orthoscope shall accommodate all inter-ocular distances from 50 mm to 75 mm.

6.4.9 Human Engineering - The location of controls and eyepieces with respect to the operator shall be such as to afford maximum comfort and functional utility during sustained operation. The design shall allow an operator to wear eyeglasses. Careful consideration shall be given to these factors in the design of the viewing system.

6.4.10 Floating Point - The floating mark or point shall be provided by the use of a pair of marks of suitable form suitably located and mounted with extreme care and consideration given to dimensional and positional stability. No moving optical elements shall be interposed between the marks and the photographs. Capability for adjusting the size of the floating mark to the optimum for all magnifications specified in 6.4.2 shall be provided. When using convergent panoramic photography and its related optics, the size of the floating mark shall not enlarge more than 1.4 times its nominal size or reduce by more than 0.7 times its nominal size.

6.4.11 Maintenance - The configuration of the viewer shall be such that adjustment, minor repairs, and replacement of parts may be made by operating personnel. Any tools required to perform the above shall be furnished by the contractor.

6.5 Plotting Device - The plotting device shall reproduce at a preselected scale the displacements of the floating mark in the corrected model and shall consist in part of a linkage with the stereoscopic viewer, drawing or viewing elements with controlled X and Y motion, and a table on which the drawing sheet is located.

6.5.1 Linkage - The linkage between the stereoviewer and drawing or viewing device shall be of highest quality. There shall be no more than .001 inch backlash or lost motion between the stereoviewer and drawing or viewing device. Provision shall be made for disconnecting this linkage so that the drawing or viewing device can be moved independently of the stereoviewer.

6.5.2 Drawing and Viewing Devices - The plotting device shall be supplied with:

a. Pencil chuck or similar drawing head.

b. Stylus for scribing on such material as "Scribe Coat".

c. A microscope of at least 10 power with reticle.

These three devices shall be easily interchangeable and shall indicate the same point on the contour chart to within .001 inch. Items 6.5.2a and 6.5.2b shall be retractible from the compilation sheet remotely at the discretion of the operator. A lamp shall be provided to illuminate the compiled manuscript around the drawing and viewing device.

6.5.3 Moving Head - The tracks for the moving head, to which are attached the devices of 6.5.2, shall be well supported and driven at both ends so as to prevent undesirable lateral motions. Limit stops shall be provided to indicate aurally and visually that the moving head has reached the limit of its travel.

6.5.4 Plotting Table - The plotting area of travel shall be at least 1100 millimeters by 1400 millimeters. The compilation surface shall be parallel to the plane determined by coordinate motions and flat to a total runout of no more than .005 inch over the entire plotting area. Along any straight line of 125 millimeters length the total runout shall not be more than .001 inch. Hold down means for the compilation material shall be provided so that the above tolerances are satisfied with this material in place. The plotting surface shall be translucent and shall be illuminated from the rear. The illumination source shall not cause the surface temperature of the table to increase by an amount which would adversely affect the dimensional characteristics of the plotting material.

6.5.5 Photo Carriage Drives - The photo carriage motions are to be driven by servos that will control the carriages in the entire ($x+\Delta x$, $y+\Delta y$) motions. The servo gear ratios shall provide the full slew rate as a servo output. A motor with a high gear power output will be incorporated to meet dynamic requirements, if necessary.

6.6 Kinematic Design - The ranges of motions, differential and combined, shall be adequate for the ranges of pitch, roll, and yaw as specified, when these values or any combination of these values, exceed the respective maximum values.

6.7 Precision of Plotted Points and Contours - The accuracy of the contour chart and plotted points produced by the Plotter Group shall be .010 inch root mean square referred to the input data at 20X magnification of photo scale to plotting scale. At higher magnifications the permissable error shall be proportionately increased reaching .015 inch root mean square at 30X.

6.8 Operator Controls - Controls shall be provided by which the operator may effect changes in tip, tilt and swing in a manner similar to that employed in standard stereoplotters. Separate hand controls for X motion and Y motion of the model shall be provided. It shall be established that a clockwise rotation of the X and Y handwheels shall cause the floating dot to appear to traverse the model from left to right and from front to back respectively. A foot control shall be provided for control of the elevation of the floating mark. A single

control wheel shall be provided to steer the floating mark at a fixed elevation (contouring mode) or at fixed values of X or Y (profiling mode). Rotary decade switches shall be provided for entering data required in the operation of the Plotter Group. All additional controls necessary to meet the requirements of this exhibit shall be provided.

6.8.1 Translation Speed - In a contouring or planimetric operation the maximum translational speeds available shall be 3 mm per second at the model scale with errors not exceeding those specified in other paragraphs. Slew speed shall be 10 mm per second. These requirements shall apply at the one to one photo to plotting scale ratio. At other ratios the maximum translational speeds consistent with the capabilities of the plotting mechanism shall be obtained.

6.9 Other Outputs - The Plotter Group shall provide an additional output in the form of a punched paper tape recording of the plotted points. This recording shall be under the control of the operator and one point shall be recorded for each actuation of a switch or push button by the operator. The recording shall contain the X, Y and elevation (relative to the spheroid) values, at model scale, pertinent to the point, recorded to a precision compatible with the accuracy of the stereoplotter (a least count of 5 microns). The stereoplotter shall provide the operator with the exact relation between model scale and plotting scale.

6.10 Photo Scales - The Plotter Group shall be suitable for accommodating pairs of photographs in which the individual photographs of a pair may differ from each other in photo scale by 10 per cent. In accordance with the requirements of convergent panoramic photography, the computer shall provide means for computing the differential scale changes by means of the following equations:

$$x = \frac{f \cos \phi \, X'''}{-Z'''} \qquad y = fe \qquad \phi = \tan^{-1} \frac{Y'''}{Z'''}$$

6.10.1 Output Scale - The Plotter Group shall provide a continuously adjustable reduction or enlargement from photo scale to plotting scale of 0.5 reduction to 30 times enlargement. The reduction and enlargement referred to is the product of the photo to model enlargement and the model to plotting enlargement. The product of these two enlargements shall be continuously adjustable.

6.11 Dynamic Performance - The error performance of the driving servo mechanisms shall be compatible with the overall 5 micron accuracy of the Plotter Group. The motions produced shall be smooth and free of jitter and other objectionable characteristics.

6.12 Methods of Establishing the Model

6.12.1 Interior Orientation - Provisions shall be made for accepting all elements of interior orientation. The computer shall automatically store the coordinates of each fiducial point in response to the pushing of an appropriate button on the control panel when the photo carriage has been properly positioned

by the operator. Principal point corrections shall be entered by means of data-entry switches. For each photograph, the computer shall find the center of gravity of the fiducial points, add the principal point corrections to the coordinates of that point (assuming mechanical kappa is zero), establish the resultant point as the origin of the photograph coordinate system, and position the photograph to that point.

6.12.2 Relative Orientation - Provisions shallbe made for recovering the relative orientation by means of any of the following techniques at the discretion of the operator.

6.12.2.1 Provision shall be made in the computer for the measurement of y parallax at any pre-determined number of points between 5 and 12 inclusive. The elements of relative orientation shall then be determined by the computer using the parallax measurements and a linearized form of the basic equation for relative orientation given below:

$$\Delta K = a_1 p_1 + a_2 p_2 + \cdots a_{12} p_{12}$$

$$\Delta W = b_1 p_1 + b_2 p_2 + \cdots b_{12} p_{12}$$

$$\Delta \phi = c_1 p_1 + c_2 p_2 + \cdots c_{12} p_{12}$$

$$\Delta by = d_1 p_1 + d_2 p_2 + \cdots d_{12} p_{12}$$

$$\Delta bz = e_1 p_1 + e_2 p_2 + \cdots e_{12} p_{12}$$

The coefficients a_i, b_i, c_i, d_i, e_i will be supplied from external sources.

6.12.2.2 Provisions will be made for the operator to clear Y parallax at the usual five points of the model by means of operator control of the values of relative orientation as being used by the computer.

6.12.3 Absolute Orientation - Provisions shall be made for recovering the absolute orientation by means of any one of the following techniques at the discretion of the operator. In every case it shall be possible for the operator to select any arbitrary point within the model as the point of tangency for the datum plane without the need for additional ground control information. The correction for earth curvature (6.2.4) shall be computed to this datum plane.

6.12.3.1 The operator will adjust the elements or absolute orientation to achieve a match by reference to the plotting point and the floating mark, between photo-identifiable control points on a base sheet and the image of the corresponding control points appearing in the stereo model respectively.

6.12.3.2 Provisions shall be made in the instrument for achieving absolute orientation by reference to tabular data of the ground coordinates of at least three photo-identifiable ground control points appearing in the model. The computer shall accept the desired coordinates of 3 photo identifiable points in the intended model scale by means of data entry switches or punched tape. The computer shall also store the actual model coordinates of each point after the photo carriages have been properly positioned by the operator. The computer shall make the necessary calculations and automatically change the appropriate elements of orientation to achieve absolute orientation. An approximate procedure may be used for this operation, provided, in most cases, where control is well distributed throughout the model, no more than 1 or 2 iterations are required.

6.12.3.3 Provisions shall be made for achieving absolute orientation from data supplied concerning the air station coordinates and values of the K, $\underline{\Phi}$, and Λ (yaw, pitch, roll) for each exposure.

6.12.3.4 Provision shall be made to locate on a print, corresponding to one of the photographs of the model, the position of the operation in the model.

7. Self Checking - The Plotter Group shall have preprogrammed problems that would be placed into the equipment which shall allow the operator to make periodic checks of the system accuracy. The problems shall cover as many component accuracy checks as possible. A diagnostic method for the computer shall be provided. The procedures for performing the self checking function shall be submitted to the Government prior to equipment delivery.

8. Electrical Controls - Electrical controls shall be provided to control the operation of the Plotter Group. The controls shall be laid out in such a way that all knobs and switches are easily located and in easy reach of the operator.

9. Air Filters - Air cooling is necessary for the proper operation of any component of the Plotter Group, the cooling air shall be filtered by means of replaceable air filter elements.